GROWTH ANALYSIS IN SEVERAL PEANUT CULTIVARS AND THE EFFECT OF PEANUT ROOT-KNOT NEMATODE (*Meloidogyne arenaria*) ON PEANUT YIELDS

By

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Growth analysis in several peanut (Arachis hypogaea L.) cultivars was studied in a two-year field experiment.

In the 1976 experiment, Florunner and Apollo peanut cultivars were selected to determine the differences in yield physiology. Thirty-six plants were sampled at one week intervals. The total phytomass and pod dry matter accumulations were measured. Flowering began at 28 days after planting for each cultivar, but Florunner stopped flowering at 85 days whereas Apollo continued to flower throughout its growing period. The average number of pods per plant of Florunner and Apollo were 34 and 30 pods, respectively. Both total and vegetative dry matter production of Florunner was not consistently higher than Apollo. Florunner produced the highest pod dry matter yield, 4.26 tons/ha at 120 days, whereas Apollo produced only 3.09 tons/ha at 134 days.

In the 1977 experiment, 22 peanut genotypes were selected to determine the differences in yield physiology. Forty plants were sampled

to determine a crop growth rate and a pod growth rate for each genotype. Total phytomass dry matter accumulations were measured to determine the crop growth rate. The pod dry matter accumulation was measured to obtain the pod growth rate. One breeding line (UF 77416) produced the highest pod dry matter yield, 7,473 kg/ha, as compared to Dixie Runner which gave the lowest yield of 3,220 kg/ha. UF 77416 had a crop growth rate of 25.8 $g/m^2/da$ and a pod growth rate of 9.5 $g/m^2/da$ compared to Dixie Runner which had 13.4 $g/m^2/da$ for the crop growth rate and only 3.6 $g/m^2/da$ for the pod growth rate. The days to maturity of 22 peanut genotypes ranged from 118 to 139. There was little difference in the crop growth rates of these 22 peanut genotypes. The average crop growth rate for the 22 breeding lines was 23.1 $g/m^2/da$. The low-producing genotypes (Dixie Runner and UF 73307) had an average pod growth rate of 3.23 $g/m^2/da$ as compared to the higher yielding genotypes which averaged 6.81 $g/m^2/da$. It was clear that the higher yielding peanut genotypes were partitioning more assimilate to the fruits than were the lower-yielding ones.

In the 1978 experiment UF 77118, an early maturing bunch-type peanut, was used to study the effect of peanut root-knot nematode, Meloidogyne arenaria (Chitwood, 1949), on the physiology of peanut yield. The nematode inoculated at seeding time and at flowering time caused the greatest decreases in the Leaf Area Index (LAI), stem dry weight, main stem height, leaf dry weight, and number of pegs and pods. This early inoculation also reduced the total phytomass; the crop growth rate and pod dry matter yield were nearly 50% less than the uninoculated treatment, and the pod growth rate was up to 58% less. Plants inoculated with the root-knot nematode at pegging and at complete ground cover were not significantly different from the uninoculated control treatment.

INTRODUCTION

Peanut (Arachis hypogaea L.) growth and development are an integrated response to many aerial, soil, and environmental factors. These factors interact often in a complex fashion. The potential yield of peanut cultivars due to breeding alone has more than doubled in the past thirty years. It seems reasonable to think that a better understanding of the physiological differences among the varieties and how they relate to yield potential should contribute to future progress in yield improvement as suggested by Duncan et al. (1978). One way to determine what changes in the physiology of the new peanut cultivars were responsible for their greatly enhanced yield potential is the use of the growth analysis studies which were first conducted by McCloud (1974). With this method, the dry matter accumulation of vegetative and reproductive plant parts were used to determine the crop growth rates and the pod growth rates. Duncan et al. (1978) found little differences in the crop growth rates among the four peanut cultivars, but the partitioning of assimilates to fruit were significantly different.

There is much information on the effect of genotype, climatic factors, cultural, and other production practices, insects, diseases, etc., on the physiological aspects of peanut yields. Information exists on the influence of root-knot nematodes on yield but not on the growth analysis of the peanut.

Meloidogyne arenaria (Chitwood, 1949), the peanut root-knot nematode, is one of the most important root-knot nematode species in the Southeastern United States. This nematode causes considerable damage to peanut (Wilson, 1948; Machmer, 1948; and Machmer, 1951). In Virginia, Miller (1960) found that M. arenaria is more devastating to peanuts than is the Northern root-knot nematode, M. hapla. In Oklahoma in nematode-infested soils, average annual yield reductions ranged up to 52% (Castillo et al., 1974). In Florida, Dickson (1973) estimated a loss of 1.6 million dollars to the peanut crop by this nematode. Estimated losses of 29 million dollars to the U. S. peanut crop in 1967-68 have been made (Anonymous, 1971).

There are many observations on the differences between nematode infected and non-infected plants on the concentrations of such elements as nitrogen, phosphorus, potassium, calcium, and magnesium. Absorption, translocation, and accumulation of mineral constituents are changed following infection (Heald and Jenkins, 1964; Jenkins and Malek, 1966). The influence of root-knot nematode on photosynthesis in the tomato plant was studied by Loveys and Bird (1973).

The objectives of this investigation were to study the growth analysis of several peanut cultivars in 1976 and 1977 and the effect of peanut root-knot nematode (Meloidogyne arenaria) on physiological aspects of peanut yields in 1978.

LITERATURE REVIEW

In the United States peanuts are grown on 600,000 hectares and rank ninth in area among the major crops. Seven states produced 98% of the 1.7 million metric tons grown in 1974 for a farm value of 576 million dollars. In Florida, peanut yields have increased rapidly. Killinger et al. (1947) reported that a record yield of 2.9 tons/ha was obtained by Stokes using Dixie Runner peanuts. In 1959 the Early Runner variety produced 5.3 tons/ha as recorded by Harris et al. (1961). Later, the peanut yield record of 6 tons/ha was set by Norden with Florunner as reported by Norden (1973). By 1974 Florunner was grown on 90% of the southeast area and accounted for 95% of the runner market type. Record yields of Florunner in the United States have reached 7.2 tons/ha; however, the record world peanut yield (9.6 tons/ha) was harvested in 1974 in Rhodesia. The cultivar was Makulu Red and the field was situated at an elevation of 1200 meters at a latitude of 29° S. Duncan and McCloud (1976) have hypothesized that the high yields in Rhodesia may result from relatively high solar radiation and favorable low temperatures which increase photosynthesis and slow fruit development to lengthen the filling period.

There has been an increase of more than 100% in yield potential resulting from changes in cultivars over the 30 years of the Florida peanut breeding program. Dixie Runner was replaced by Early Runner which in turn was replaced by Florunner which is now the most widely grown peanut in the United States. In 1977, Early Bunch was released as the newest

high yielding peanut variety. Duncan et al. (1978) identified and evaluated the physiological changes made during the course of this varietal improvement that are responsible for the great increase in yield potential. Differences in three physiological processes were found to explain most of the yield variation among the peanut cultivars: the partitioning of assimilate between vegetative and reproductive parts, the length of the filling period, and the rate of fruit establishment. Of these, the partitioning of assimilate had the greatest effect on fruit yield.

Partitioning of Assimilates

Partitioning is defined as the fraction of daily photosynthate that is allocated to pods and seeds as opposed to vegetative growth. Duncan et al. (1978) defined partitioning as the division of recent assimilate between reproductive and vegetative plant parts. They estimated less than 50% of recent assimilates were being used for fruit growth at the end of the fruit loading period for the lowest-yielding peanut cultivar, while for the highest-yielding peanut cultivars 90% of recent assimilates were being used for fruit growth as the plant completed its fruit loading. Hesketh and Peters (1978) proposed that when studying partitioning, a nutritional budget for the growing plant should be developed on an organ-by-organ basis. Each organ, depending upon its internal environment, can utilize certain amounts of photosynthate during a 24-hour period. If supply is less than demand, growth is slowed, priorities for photosynthate are set, and organs are rendered dormant or are aborted or shed, all of which affect subsequent potential demand for photosynthate.

The problem of assimilate distribution is determined by photosynthesis and by the strength and proximity of the various sinks, modified by the pattern of vascular connections and environmental conditions (Wardlaw, 1968). In sugarbeet, both roots and tops had a marked influence on partitioning of assimilate. Theurer et al. (1978) found that the root had a significantly greater effect than the top on partitioning of assimilate and for sucrose storage. Most of the carbohydrate in the grain of barley and other cereals is formed from CO_2 assimilated after the head emerges. The head and awns, if present, contribute 15-40% of the final grain dry weight (Thorne, 1959).

In sorghum, Sung and Krieg (1978) reported that the major effect of water stress was a reduction in the daily photosynthate produced due both to leaf area reduction and photosynthetic rate reductions. They found that during panicle differentiation, the expanding leaves represented the major sink of both non-stressed and stressed plants. Evans (1975) found in sugarbeet that a limiting supply of assimilate usually is distributed preferentially to the young leaves, but goes to the roots in plants under water stress.

The pattern of distribution changes as wheat plants grow and develop new leaves and new sinks (Rawson and Hofstra, 1969). During the period of grain growth, the flag leaves are the main suppliers to the ear, while the lower leaves support the roots and new tillers. Removal of the flag leaf causes the leaves below it to supply more to the ear, while shading of the lower leaves may cause the flag leaf to support the roots (King et al., 1967). Wardlaw (1968) found that in crops with many axillary inflorescences, such as pea, soybean, or cotton, each inflorescence is usually supported mainly by its substending

leaf. In soybean, Chatterton and Silvius (1978) reported that transformation of carbon into leaf starch is a regulated or programmed process and not simply the result of a deficiency in the capacity of soybean to synthesize and translocate sucrose at a rate proportional to the CO_2 fixation rate.

Crop Growth Rate

Growth analyses are helpful in understanding the general pattern of plant development. Milthorpe and Moorby (1974) reported that the dry weight (or energy content) per unit area Y, of any one crop, usually follows an approximately S-shaped curve. The difference between two consecutive points of any series gives the average crop growth rate over the period. Hanway and Weber (1971) obtained crop growth rates in soybean during the linear phase varying from 8.8 to 14.9 $g/m^2/da$ among cultivars. The highest crop growth rate reported for soybean is 17.2 $g/m^2/da$ (Buttery, 1969, 1970). Shibles and Weber (1965, 1966) found that crop growth rate in soybean is a function of intercepted irradiance. The leaf area index (LAI) required for 95% light interception ranges from 3.1 to 4.5 depending upon planting density and spatial arrangement. McGraw (1977) reported that the crop growth rate of the Florunner peanut cultivar obtained from the linear growth phase was 21.1 $g/m^2/da$. During the linear growth phase the crop growth rate represents the maximum photosynthetic rate for the crop canopy. Kumura (1968) and Hansen (1972) found that maximum canopy net photosynthetic rate reported for soybean ranges as high a 7 $gCO_2m^{-2}hr^{-1}$ and rates exceeding 5 $gCO_2m^{-2}hr^{-1}$ under high irradiance commonly are attained. The rate of crop photosynthesis depends on the leaf area index (LAI), structure of

the canopy, and photosynthetic rate per unit leaf area. Initial canopy development tends to be slow, with the result that light interception during early crop growth may be low, even when growing conditions are favorable; Watson (1971) believes this to be a major source of inefficiency in crop production systems.

Fruit Growth Rate

Patel and Seshadri (1935) reported that after the peanut peg had attained its maximum penetration into the soil, the shell formed and rapidly attained its maximum size and fresh weight. At the time the peanut fruit attained its maximum size, the shell contained only a weakly developed inner layer which collapsed on dessication. At this stage, the shell was composed mainly of fragile parenchymatous tissue containing a very small amount of total solids. After the peanut shell had developed to full size, its fresh weight declined very rapidly as the seed expanded into the shell cavity. Although the fresh weight declined, the dry weight of the shell continued to increase slowly during the next week or two. The dry weight then remained steady for a time and finally declined slowly as seeds approached maturity. The seeds developed only slightly until the shell had reached its full size. After this lag, the fresh and dry weights of seed increased rapidly, the rate of increase in fresh and dry weight was most rapid in the early stages of seed enlargement. The rate then gradually declined for a period of more than a month, but it was difficult to determine exactly when further dry weight accumulation ceased (Schenk, 1961).

Boote (1976) studied the fruit growth rate of the Florunner peanut cultivar under normal conditions in a field experiment. He found that fruit set during the first four weeks of pegging had a similar linear

growth rate (33.5 mg/da/fruit) between 1 and 7 weeks of fruit age and accounted for 78% of yield at 133 days. Fruit set during the 5th to 7th week of pegging grew at slower rates. Progressively smaller pod size occured for the later fruits, presumably because older fruits were using photosynthate and less photosynthate was available for later set fruits while they were in the pod expansion phase. An (1978) found that shading the Florunner peanut cultivar at pegging and pod filling stage reduced total peg and pod number and reduced fruit dry weight. Shading for 21 days during the pod filling stage caused the greatest yield loss (30%). Shading during maturity slightly decreased yield by decreasing the percentage of fully-formed fruits and reducing seed growth of smaller, later fruits. The period of pod filling, from 83 to 104 days after planting, seemed to be the period most sensitive to low light intensity with respect to yield reduction. She concluded that shading caused a major reduction in number of fruits or pegs, but had relatively minor, although significant, effects on fruit growth rate. According to McGraw (1977), the Florunner peanut variety has a maximum pod growth rate of 9.3 $g/m^2/da$. He reported that the amount of photosynthate required to produce a given amount of pod dry weight was found to be approximately 1.65 times as much as was required for an equal dry weight of vegetative component. Duncan et al. (1978) reported that peanut, soybean, and corn must establish their fruit loads by adding fruits progressively until a final fruit number is reached. Smith (1954) and Cahaner and Ashri (1974) found that the time required from fertilization to pod maturity of a Virginia-type peanut cultivar is about 2 months. At any harvest date some of the pods will still be immature, and these, when harvested, lower the quality of the yield and

represent a loss of metabolite. Troeger et al. (1976) studied the peg attachment force (PAF) of peanut cultivars, by using an unbonded strain gauge transducer measurement. They found that Spanish-type cultivars had the highest PAF of 1100-1250 g, runner-type cultivars the lowest at 660-780 g, and Virginia-type cultivars were intermediate. They concluded that cultivars with the highest ratio of PAF:pod projected area showed the lowest losses in the field. PAF increased with increasing moisture content and decreased with increased maturity. Baumann and Norden (1971) studied the peg strength of five peanut cultivars and found that peg strength depends on the growth habit, pegging zone, and the pod size. They found that in Florida field trials, Florigiant, a runner growth habit, is generally considered to be moderately weak-pegged and, therefore, larger pod losses often occur during harvesting. These losses may be due to its deep pegging zone and large pods (Baumann and Norden, 1971).

Williams et al. (1976) examined the effect of defoliation and pod removal on growth and dry matter distribution in peanut. They found that defoliation decreased both stem and pod growth rate, but the decrease in stem growth rate was proportionately greater than that in pod growth rate. Pod growth rate was increased by pod removal and was decreased by defoliation.

Effects of Root-Knot Nematode on Crop Yield

Many factors are recognized as limiting to crop growth. Some factors (weeds, insects, diseases) detract from yield potential, that is, they reduce the yield that might have been achieved with the particular crop under that environment. Crop losses due to plant diseases appear in different forms but commonly are losses in yield and deterioration in quality. The yield and quality losses increase the cost of production per unit of product (Khan, 1972).

Before 1949 all root-knot nematodes were known as Heterodera marioni. Chitwood (1949) removed them from Heterodera, placed them in a new genus, Meloidogyne, and divided them into five species. Most plants attacked by most species of Meloidogyne form more or less pronounced root galls. Exceptions are cotton and brassicas attacked by Meloidogyne artiellia, and many of the Gramineae (but M. kikuyensis does cause galls in kikuyu grass) (Franklin, 1965).

Peanut is resistant to most species of root-knot nematodes and has been used extensively in rotations as a root-knot nematode resistant crop. However, Cooper (1950) examined some peanut plants in North Carolina and found that the roots were discolored, short, matted, and had numerous small galls. These galls were from one to three times the diameter of normal roots and contained from one to four female root-knot nematodes. He reported that the relationship of this nematode to others reported on peanut was not known, but apparently was not the strain which commonly attacks tobacco. He reported that infestation of peanut by this nematode may have been a factor causing poor plant growth, especially when peanut follows peanut in the rotation. In 1951, Machmer reported that there were two species of root-knot nematodes in the eastern United States which will infect peanut, and that they can cause serious crop losses in the regions where they occur. One of the species was reported from North Carolina by Christie and Albin (1944) and was described as Meloidogyne hapla (Chitwood, 1949). M. hapla appears to be the prevailing root-knot nematode of the northeastern states. The other was identified as M. arenaria (Chitwood, 1949) from material collected in southeast Georgia by Machmer. As reported by Wilson (1948) and by Machmer (1948) this root-knot nematode of peanut occurs over a considerable area

in the lower Chattahoochee River basin where peanut is an important field crop. Machmer (1951) also found that galling occurred on all underground parts of peanut plants including the pods which appear warty. He reported that pods and stems were often galled heavily and severed easily, and that early infection of the peg was detrimental to the seed embryo.

Weischer and Steudel (1972) reported that about 150 hosts are recorded for Meloidogyne arenaria; only some varieties of cotton, some species of Nicotiana, Crotalaria, and strawberry are known non-hosts. Crofton (1966) reported that the first stage larva of the root-knot nematode develops and remains in the egg until after the first molt. The second stage emerges and enters the host plant root near the tip. As it feeds, the larva becomes swollen and the plant tissue develops giant cells on which the larva feeds; the area infected becomes enlarged and deformed. Williams (1969) found that heavy larval infections stop root growth by affecting the meristematic zone. The pressure from the expanding giant cells, maturing nematodes, and egg masses causes mechanical damage to the root tissues, such as blockage or malformation of the xylem vessels. Crofton (1966) found that the nematodes undergo the usual series of molts to form the adult males and females. The posterior end of the female is usually protruded through the surface of the gall, and the female lays 300-500 eggs in a gelatinous matrix referred to as an egg mass. Egg masses are found on the surface of the roots. The whole life cycle may take as little as three weeks so that several cycles may occur during the growing season. The galls, which may contain eggs and larvae, are formed by the host tissues.

Madamba et al. (1965) indicated that the growth of pepper, peanut, and Crotalaria was stimulated by various species of Meloidogyne.

Stimulation occurred primarily at the lower infection levels; at high inoculum levels growth was suppressed.

Root-knot nematodes are implicated in several disease complexes. Martin et al. (1956) found that Fusarium wilt of cotton is more severe in the presence of root-knot nematodes. A similar association between this fungus and root-knot nematodes was shown in alfalfa by McGuire et al. (1958), and in cowpea by Thomason et al. (1959). In peanut, Garcia (1974) found that there was an interaction of several fungi with Meloidogyne arenaria. Recent studies have been made by King et al. (1976) and Rodriquez-Kabana et al. (1976, 1977) to determine the effectiveness of nematicides in combination with a fungicide for control of Meloidogyne arenaria and Southern blight (Sclerotium rolfsii) on Florunner peanut. They found that the nematicide-fungicide combination resulted in increased yield over that of the nematicide alone. Powell and Nusbaum (1960) found that black shank of tobacco due to Phytophthora parasitica nicotianae was more severe in the presence of Meloidogyne incognita than without it.

Stewart and Schindler (1956) showed that the bacterial diseases of carnation caused by Pseudomonas caryophylli was increased in the presence of root-knot nematodes. They considered that mechanical damage done by the nematodes allowed the bacteria to enter the roots, because mechanical root wounding also resulted in increased bacterial wilt. A similar observation was made by Lucas et al. (1955) in tobacco plants.

No association between root-knot nematodes and any virus disease of plants had been recorded (Franklin, 1965).

The Effects of Root-Knot Nematodes on Physiological Aspects of Crop Yields

There are some responses which occur commonly in nematode infected plants. Wallace (1973), Goodman et al. (1967), and Heitefuss (1966) reported that photosynthesis is reduced, respiration is increased, new enzymes are often formed. The metabolism of growth regulators changes in various ways and auxin production is commonly excessive. In response to restricted waterflow in the plants vessels, transpiration is reduced. Consequently, the stomates close, at least initially, there is a localized accumulation of ethylene and auxins, and these in turn affect cell permeability and cause yellowing of foliage, epinasty, or premature leaf abscission. Woolhouse (1967) found a marked increase in photosynthetic rates of the remaining leaves in the control seedlings following pruning, which likely resulted from an enhanced supply of root-derived nutrients to the remaining leaves. Bird (1961) suggested that root-knot nematodes interfere with the production or translocation of root-derived nutrients that instead may be required by the developing syncytia induced by the nematode in the root.

Loveys and Bird (1973) measured the rates of photosynthesis of tomato seedlings for 22 days after heavy infestation with Meloidogyne javanica larvae. A decrease in photosynthesis, compared with uninfested controls, was detected within 2 days of invasion by the larvae, and this decrease was maintained throughout subsequent growth. During early stages of infestation the decreased photosynthesis was highly significant when expressed on the basis of fresh weight, leaf area, or total chlorophyll content. They suggested that this response perhaps results

from a reduced supply of root-derived nutrients which influence rate of photosynthesis.

Webster (1972) reported that plant parasitic nematodes exert an inhibitory effect on yield in various crops. Furthermore, it has been shown by Bird (1970) that plant growth may be reduced significantly by heavy infestation of root-knot nematodes. Information on physiological changes in isolated root material has been reported from a number of sources (Bird and Millerd, 1962; Owens and Rubinstein, 1966). No reports are published on photosynthetic or other physiological changes associated with this host-parasite relationship in the intact plant, although a decrease in growth hormones from extracts of root tissue and xylem exudate has been reported by Brueske and Bergeson (1972).

Uritani (1971) found that as the parasite penetrates cells, protein changes occur in adjacent cells. Frequently, there is an activation of phenylalanine ammonia-lyase activity, an increase in respiration, increased activity of mitochondria, and increased activity of some enzymes in the glycolytic and pentose phosphate pathways. Arising from these changes is a release of ethylene which may be responsible for primary and secondary protein changes; it may also act as a hormone by activating some specific site of plant nuclear DNA. Rubinstein and Owens (1964) studied the synthesis of DNA and RNA in the syncytia of tomato infected with the root-knot nematode (M. incognita acrita) and indicated that the developing syncytium is a region of intense RNA and DNA synthesis. DNA, unlike RNA, seemed to be dependent on a close association with the feeding nematodes. Bird (1972) reported that in bean, tomato, and cabbage infected with Meloidogyne javanica the syncytial and nuclear growth and DNA content increased until just before the developing females started

to lay eggs. More DNA and RNA means that additional amino acide are available for incorporation into proteins; it does not necessarily follow that there will be an increase in free amino acids in the infected plant, in fact they could decrease (Wallace, 1973). Kannan (1967) found that the increased activity of dehydrogenases involved in the carbohydrate metabolism in galls on plants infected with Meloidogyne incognita acrita stimulated respiratory activity, which indicates that the plant is combating the infection.

Plant growth is regulated by growth-promoting substances as hormones such as auxins, gibberellins, cytokinins, and ethylene. Changes in the concentrations of these substances produce changes in the growth and form of tissues and organs in the plant. Setty and Wheeler (1968) examined roots of tomato plants with galls of Meloidogyne spp. and found that although the concentration of auxin was the same in infected and uninfected roots, the total amount in the roots of the infected plants was greater because of the larger root mass. Increased auxin levels in Meloidogyne galls also have been reported by Yu and Viglierchio (1964) and Viglierchio and Yu (1968).

Most plant and animal cells can repair wounded tissue. Owens and Specht (1964) and Wallace (1973) have suggested that the ability of plants to repair damaged tissue is a well known phenomenon. The callus formed by the cambium at wounds has a protective as well as a repairing function. The growth substances, auxin, and traumatic acid are involved in the response.

Bergeson (1966) found that the excesses of nitrogen and potassium in the roots of tomato infected with root-knot nematode (M. incognita) were probably caused by transporation of these minerals from non-infected tissues to the infection site.

Kende (1965), Phillips and Jones (1964), and Brueske and Bergeson (1972) found that both cytokinins and gibberellins in the plant root tissue and xylem exudate are decreased in plants infected with root-knot nematodes as compared with uninfested control plants. Wallace (1973) proposed that cytokinins influence cell division but their activity depends on the presence of auxin. These growth regulators also influence the rate of senescence possibly through influencing messenger RNA synthesis, thereby preventing the genes from being repressed and allowing the cells to continue their synthesis of both RNA and protein. Loveys and Bird (1973) suggested that root-knot nematodes inhibit photosynthesis in plants by interfering with the synthesis and/or translocation of growth hormones in their host roots. They also suggested that root damage caused by the nematode could lead to water stress in the plant and cause partial closure of stomates which could result in a difference in the rate of CO_2 fixation.

EXPERIMENT I. YIELD
PHYSIOLOGY OF FLORUNNER AND APOLLO PEANUT

Objective

The objective of this investigation was to determine the physiological factors which contribute to high yield of Florunner and Apollo peanut cultivars grown under the same environment.

Materials and Methods

Florunner, a high-yielding runner type cultivar from the U.S., and Apollo, a late-maturing bunch type cultivar from Rhodesia, were grown in four replications in a randomized block design. The experiment was initiated on June 3, 1976, at the Agronomy Farm, University of Florida. A 2-10-10 fertilizer at 560 kilograms per hectare was applied broadcast, after which the field was turned and disked. One seed was planted per hill at a spacing of 25 x 30 cm. This spacing resulted in 12.9 plants per square meter which is within the range of optimum yield for peanut. Insecticides, fungicides, and herbicides were applied at rates recommended for maximum yield. Overhead irrigation was applied at planting to obtain uniform emergence and during periods of low precipitation to insure adequate soil moisture.

Sampling began 15 days after planting and continued at seven-day intervals. In order to insure that full maturity was reached the plants were sampled until a decline in pod dry matter yield was recorded. At each sampling 36 plants were pulled by hand from each sub-plot. The 36-plant samples were used to determine the dry weight yields of the vegetative

and reproductive plant parts. The plant samples were dried at 70° C and the total dry weights and pod dry weights recorded. The vegetative dry weight was obtained by subtraction of pod dry weight from total weight. The number of pods per plant was averaged from 10 plant samples. The percent ground cover was obtained from five samples within a main block for each variety and the average of these 20 samples is presented. Observations were taken each week until 100% ground cover was obtained. The date of flowering was recorded.

Meteorological data consisting of air temperature, precipitation, and solar radiation were obtained from the Agronomy Department weather station. The weather in 1976 was quite favorable for peanut production (Fig. 1).

Results and Discussion

Ground Cover

Florunner and Apollo peanut cultivars began to emerge seven days after planting. At the first sample date, 15 days after planting, the ground cover for both Florunner and Apollo was approximately 11%. Ground cover increased geometrically and by day 36 had reached nearly 50% for both cultivars, and reached 100% by day 64. Canopy photosynthesis maximized at this period as a result of the full ground cover. McCloud (1974) reported that the canopy of Florunner reached full ground cover at 64 days when LAI was 3.0. McGraw (1977) observed that after Florunner cultivars reached 100% ground cover, an increase in LAI did not increase the crop growth rate. Kassam et al. (1975) found that in Nigeria, the LAI of peanut plants increased from 2.2 at 60 days after sowing to 5.5 in late August, and then decreased to 2.1 in late September.

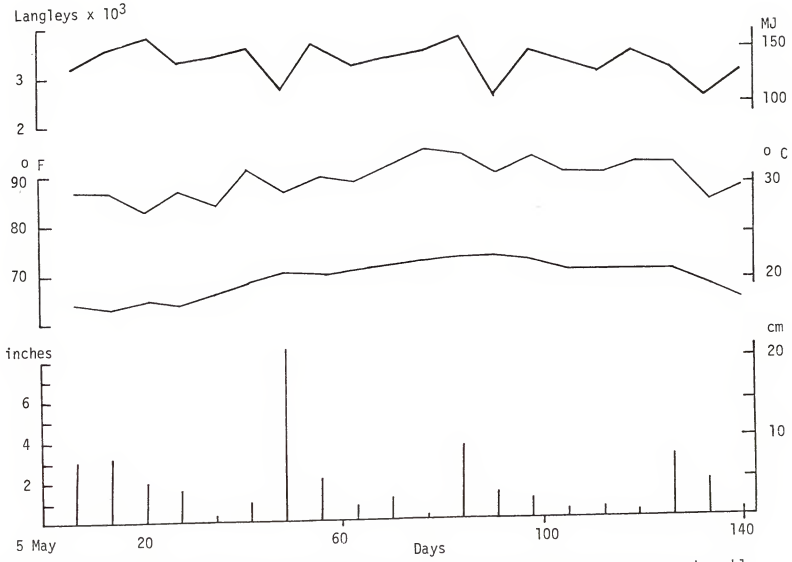

Figure 1. Weekly solar radiation, average weekly maximum and minimum temperatures, and weekly rainfall at Gainesville, Florida, during the 1976 peanut growing season.

Flowering and Podding

Florunner and Apollo both started flowering at 28 days. At 71 days Florunner reached its highest number of flowers, about 45 per plant, after which the number of flowers declined rapidly. In contrast, Apollo continued to produce flowers after pod numbers had reached a maximum. McCloud (1974) reported that flowering of Florunner began at about 30 days and had almost ended at 87 days after seeding. McGraw (1977) also reported that the first flowers of Florunner started on day 35 and the number of flowers declined sharply after day 70.

At 43 days both cultivars started pegging. At 120 days Florunner and Apollo produced 440 and 350 pods/m^2, respectively. Hildebrand and Dube (1976) reported that under Rhodesian conditions the numbers of pods per plant of Apollo and Florunner were 33 and 36, respectively, at 166 days. McGraw (1977) reported that Florunner produced 450 pods/m^2 at about 84 days and the pods began to fill at about day 70. Williams et al. (1975) reported that the number of pegs per plant increased with temperature, but the proportion of pegs which produced pods increased as the temperature decreased. Ono and Ozaki (1974) reported that the pod weight began to increase at about 30 days after first flowering and reached its highest value at 90 or 100 days. Ono et al. (1975) also found that soil temperature and soil moisture in the podding zone affected pod development. They reported an optimum soil temperature of 31-33° C, a minimum soil temperature of 15-17° C, and a maximum of 37-39° C. Optimum soil moisture content was 40%, and when soil moisture content was less than 40%, podding percentage and pod thickening were reduced. The most critical temperature period for pod filling was 20-30 days after peg penetration.

Growth Rate

The growth of Florunner and Apollo peanut cultivars is presented in Figures 2 and 3. During the first six weeks total phytomass production of the two peanut cultivars was exponential. The linear growth phase for both cultivars began around 50 days. The crop growth rate from 43 to 64 days of the Florunner cultivar was 125 kg/ha/da, and the equation for this relationship is $Y = -4034.97 + 125.471\ X$ with an r of 0.958. Apollo had a crop growth rate of 126 kg/ha/da ($Y = -4319.657 + 125.857\ X$) with an r of 0.976. These values show a good fit for linear regression. The crop growth rate of these two peanut cultivars was not significantly different. Since this period is during the linear growth phase and prior to kernel development, this growth rate represents the maximum canopy photosynthetic rate.

After day 64 the seeds began to fill and the development of the plant shifted from vegetative growth to the reproductive phase, and the rate of dry matter accumulation of the vegetative component of Florunner began to decline, Figure 2. In contrast, Apollo continued substantial vegetative growth for 100 days, Figure 3.

Florunner and Apollo started the pod filling period at 50 days when the first pods appeared and continued to the highest pod yield at 120 days for Florunner and 134 days for Apollo, Table 1. The highest pod dry matter yield of Florunner was 4,258 kg/ha as compared to Apollo which produced only 3,087 kg/ha. The pod growth rate was 60 kg/ha/da for Florunner, whereas Apollo produced only 43 kg/ha/da. The linear pod filling rate of Florunner was taken from 50 to 106 days and for Apollo from 50 to 134 days. Analysis of this linear pod filling phase for Florunner gave a regression equation $Y = -3853.6152 + 59.958\ X$ ($r = 0.921$) as compared

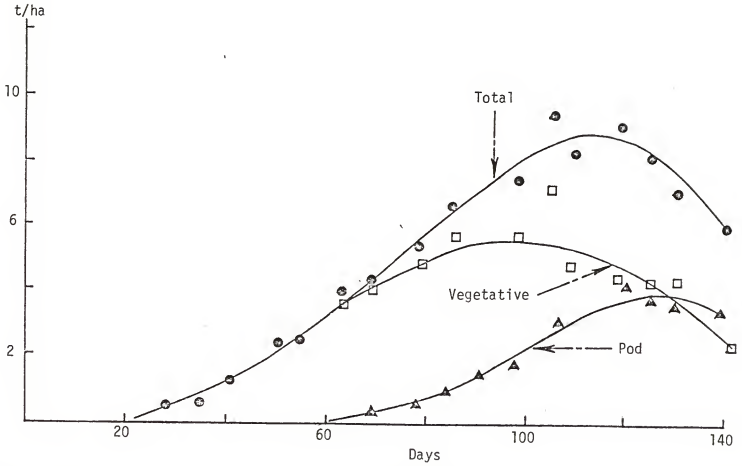

Figure 2. Total phytomass and vegetative and pod components for Florunner peanuts planted June 3, 1976.

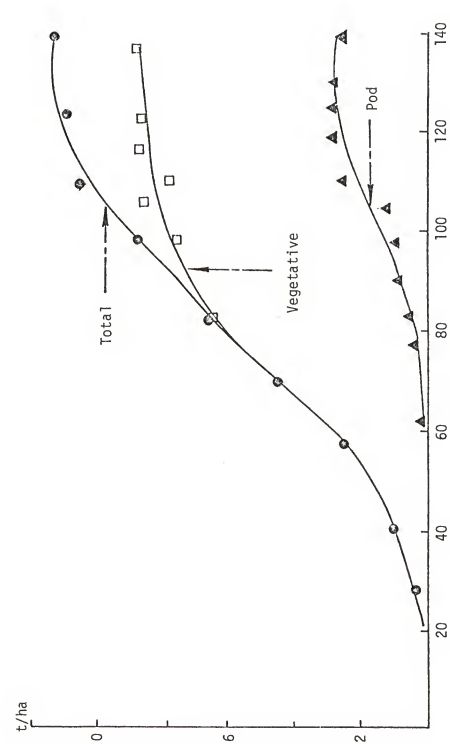

Figure 3. Total phytomass dry weight and pod component for Apollo peanuts planted June 3, 1976.

to Apollo Y = -2888.306 + 43.070 X (r = 0.916). From these relationships I found a maximum pod growth rate of 94 kg/ha/da for Florunner and 41 kg/ha/da for Apollo. The linear pod growth rate of Florunner was taken from 85 to 106 days and for Apollo from 85 to 113 days. Analysis of this linear maximum pod growth rate for Florunner gave a regression equation Y = -7380.9285 + 93.928 X (r = 0.960) as compared to Apollo Y = -3075.68 + 41.085 X (r = 0.953). McGraw (1977) obtained a similar (93 kg/ha/da) pod growth rate for Florunner.

Partitioning of Photosynthate

As the seed began to fill the amount of photosynthate needed for filling the pods increased. During this period the plants increased the partitioning of photosynthate to pod development. McGraw (1977) calculated the partitioning coefficient of Florunner at about 73%. He calculated partitioning by dividing the linear pod filling rate by linear vegetative growth rate and multiplying by 1.65. In my experiment, Florunner had a calculated partitioning coefficient of 79% as compared to 56% for Apollo. Observations support the contention that Florunner partitioned less dry matter to vegetative than to reproductive growth during the pod filling period since its leaves yellow by the end of filling and many leaves senesce. The Apollo vegetation remained green in the late stages of pod filling. Even with leaf loss the vegetative growth curve for Apollo did not decline but continued to increase to maturity (Figure 3, Table 1). The Florunner cultivar reached a maximum pod yield at 120 days compared to 135 days for Apollo (Table 1). Afterward the recoverable pod dry matter yield declined rapidly as the peg attachment deteriorated.

Florunner matures earlier than Apollo. At 134 days Florunner dropped many leaves while Apollo was still growing with the canopy still green. Norden et al. (1969) reported that Florunner planted under Gainesville conditions matures in 134 days, while Hildebrand and Dube (1976) reported that Florunner planted in Rhodesia matures in 166 days and Apollo in 173 days. This evidence suggests that the growth of peanut cultivars is influenced greatly by the temperature occurring at the different locations, and thus likely is a factor influencing adaptation of high-yielding cultivars to a particular environment.

Table 1. Total phytomass, vegetative, and pod dry weight for Florunner and Apollo peanut cultivars planted June 3, 1976.

Days After Planting	Florunner			Apollo		
	Vegetative Dry Weight	Pod Dry Weight	Total Dry Weight	Vegetative Dry Weight	Pod Dry Weight	Total Dry Weight
	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
15	128	--	128	132	--	132
22	243	--	243	278	--	278
29	417	--	417	481	--	481
36	793	--	793	941	--	941
43	1221	--	1221	1201	--	1201
50	2628	13	2640	2186	2	2188
57	2718	14	2732	2336	7	2344
64	4052	67	4118	3646	31	3676
71	4626	228	4854	4774	88	4862
78	5281	425	5706	5908	208	6116
85	5852	788	6640	7077	398	7476
92	5648	1121	6768	8046	811	8857
99	5708	1642	7348	7884	834	8719
106	6949	2806	9756	8515	1348	9863
113	4784	3442	8228	7886	2782	10668
120	4712 b	4259 a	8942 b	8468	2839	11307
127	4323	3697	8020	8460	3038	11498
134	4510	3158	7668	8810 a	3087 b	11897 a
141	2368	3519	5887	8469	2956	11425
148				9542	2528	12070

Means with the same letter are not significantly different at alpha level = 0.05.
CV (vegetative dry weight) = 10.78
CV (pod dry weight) = 12.28
CV (total dry weight) = 10.02

EXPERIMENT II. GROWTH ANALYSIS IN TWENTY-TWO PEANUT GENOTYPES

Objective

The objective of this experiment was to determine the yield, crop growth rate, and pod growth rate of 22 peanut genotypes.

Materials and Methods

Peanut seed of 22 genotypes (Table 2) was obtained from Dr. A. J. Norden, Department of Agronomy, University of Florida, and tested in a growth analysis study. The experimental design, spacing, fertilization, crop protection, and irrigation treatment were conducted the same as in Experiment I. The experiment was initiated on May 6, 1977, at the Agronomy Farm, University of Florida.

Sampling began when the plants reached full ground cover—69 days after planting—sampling began and continued until the crop matured. At each sampling 40 plants were pulled by hand from each sub-plot. The 40-plant samples were used to determine the dry weight yields of the vegetative and reproductive plant parts. The pods and vegetative components were dried at 90° C, separated mechanically, and the dry weights recorded.

Meteorological data for 1977 consisting of air temperature, precipitation, and solar radiation (Figure 4) were obtained from the Agronomy Department weather station.

Table 2. The 22 peanut genotypes used in the 1977 growth and analysis study.

Cultivar or Breeding Line	Seed Source*
Early Bunch	76-I-S-105
Florunner	76-I-1
UF 77118	76-2945
Dixie Runner	76-807
UF 73307	76-I-99
UF 77303	76-I-45
Storer's Jumbo Bunch	76-2351
UF 77114	76-404
UF 77405	76-409
UF 77113	76-412
UF 77414	76-413
UF 77402	76-1883
UF 77710	76-1977
UF 77117	76-2665
UF 77116	76-518
UF 77707	76-2551
UF 77416	76-416
Tifrun	76-310
GK 3	76-305
UF 77602	76-1453
UF 771127	76-2623
UF 77617	76-1641

* Dr. A. J. Norden, Department of Agronomy, University of Florida, Gainesville.

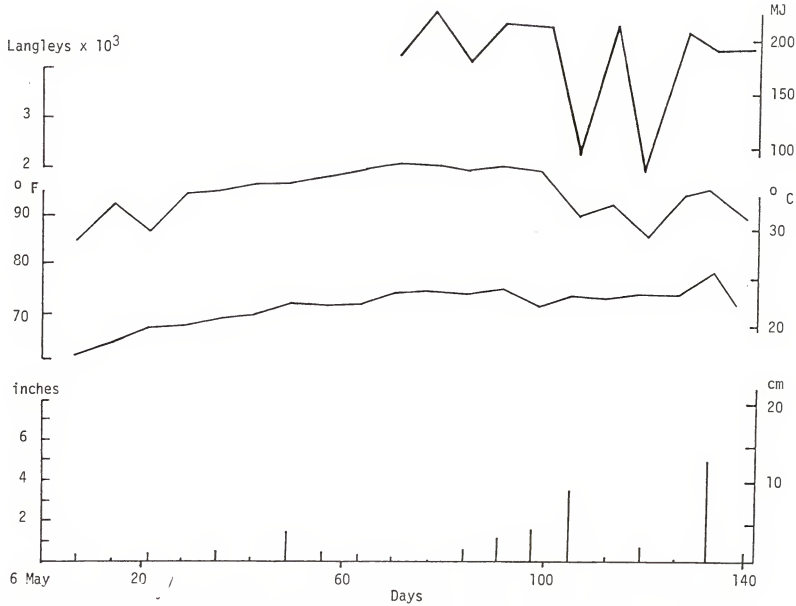

Figure 4. Weekly solar radiation, average weekly maximum and minimum temperatures, and weekly rainfall at Gainesville, Florida, during the 1977 peanut growing season.

Results and Discussion

The crop growth rates and pod growth rates of 22 peanut genotypes are presented in Table 3. For vegetative growth the linear phase began around 69 days, and the linear pod growth rate was started on 90 days after planting. Early Bunch and UF 771127 had the highest crop growth rates, 29.9 g/m^2/da, as compared to the Storer's Jumbo and Dixie Runner cultivars which produced only 19.7 and 13.4 g/m^2/da. The other 18 genotypes produced crop growth rates near the average for the 22 peanut genotypes, which was 22.5 g/m^2/da. Duncan et al. (1978) reported that there was little difference in the rate of canopy photosynthesis. They found that all cultivars produced vegetative dry matter at essentially the same rate per square meter after the canopy closed and before fruit development. In this experiment Florunner produced a crop growth rate of 21.2 g/m^2/da. A similar observation was made by McGraw (1977) who reported that Florunner produced a crop growth rate of 21 g/m^2/da. In Experiment I, I found the crop growth rate of Florunner to be only 12.5 g/m^2/da. The significant difference in the crop growth of Florunner between the 1976 and 1977 seasons is a result of heavy summer rains in 1976 which caused increasing diseases and weed problems, and decreasing percent solar radiation interception. Shibles and Weber (1966) found that dry matter production of the soybean plant was a function of percent solar radiation interception regardless of planting pattern. In 1965, Shibles and Weber found that as the soybean plant growth progressed, increasing leaf area development resulted in increasing occupancy of interplant spaces, and, consequently, increasing percent solar radiation interception which in turn, resulted in an increasing rate of dry matter production. Hanway and Weber (1971) reported that the daily rates of

Table 3. Regression equation analyses for the crop growth rate and pod growth rate of 22 peanut genotypes.

Genotype	Crop Growth Rate		Pod Growth Rate	
	$g/m^2/da$		$g/m^2/da$	
Early Bunch	Y = -1234.86 + 29.8817 X	r = 0.868	Y = -127.377 + 6.42 X	r = 0.948
Florunner	Y = -744.00 + 21.1946 X	r = 0.877	Y = -235.825 + 5.924 X	r = 0.954
UF 77118	Y = -755.011 + 22.498 X	r = 0.838	Y = -341.08 + 7.396 X	r = 0.997
Dixie Runner	Y = -160.124 + 13.388 X	r = 0.876	Y = -149.841 + 3.606 X	r = 0.829
UF 73307	Y = -963.642 + 24.959 X	r = 0.858	Y = 77.495 + 2.851 X	r = 0.999
UF 77303	Y = -829.178 + 24.9362 X	r = 0.847	Y = -87.763 + 5.343 X	r = 0.865
Storer's Jumbo Bunch	Y = -530.778 + 19.716 X	r = 0.9659	Y = -476.031 + 8.691 X	r = 0.934
UF 77114	Y = -737.16 + 22.439 X	r = 0.927	Y = -35.866 + 4.502 X	r = 0.998
UF 77405	Y = -917.027 + 24.4816 X	r = 0.911	Y = -300.8751 + 7.143 X	r = 0.976
UF 77113	Y = -683.549 + 21.017 X	r = 0.922	Y = -212.921 + 5.942 X	r = 0.901
UF 77414	Y = -899.06 + 23.845 X	r = 0.911	Y = -155.681 + 5.375 X	r = 0.96
UF 77402	Y = -612.574 + 21.288 X	r = 0.861	Y = -467.914 + 8.163 X	r = 0.987
UF 77710	Y = -846.613 + 22.897 X	r = 0.855	Y = -348.848 + 7.753 X	r = 0.946
UF 77117	Y = -825.842 + 23.669 X	r = 0.910	Y = -515.132 + 9.061 X	r = 0.988
UF 77116	Y = -887.286 + 21.502 X	r = 0.852	Y = -369.872 + 7.669 X	r = 0.997
UF 77707	Y = -971.461 + 24.447 X	r = 0.935	Y = -320.926 + 7.552 X	r = 0.999
UF 77416	Y = -899.566 + 25.800 X	r = 0.979	Y = -581.125 + 9.517 X	r = 0.997
Tifrun	Y = -699.9124 + 21.826 X	r = 0.889	Y = -274.803 + 6.699 X	r = 0.958
GK 3	Y = -729.388 + 22.221 X	r = 0.935	Y = -231.855 + 5.932 X	r = 0.999
UF 77602	Y = -571.941 + 20.583 X	r = 0.866	Y = -207.422 + 6.092 X	r = 0.953
UF 771127	Y = -1373.76 + 29.905 X	r = 0.915	Y = 10.444 + 4.210 X	r = 0.855
UF 77617	Y = -1054.36 + 26.722 X	r = 0.955	Y = -215.2461 + 6.908 X	r = 0.999

dry matter accumulation in the soybean plant varied among varieties from 8.8 to 14.9 g/m^2/da.

Two peanut breeding lines (UF 77416 and UF 77117) produced the highest pod growth rate of 9.52 and 9.06 g/m^2/da, respectively, as compared to Dixie Runner and UF 73307 genotypes which obtained only 3.6 and 2.85 g/m^2/da (Table 3). Duncan et al. (1978) reported that apparently the low-producing cultivars were partitioning less assimilate to fruit and more to continuing top growth than the high producing peanut cultivars. They estimated that about 90% of recent assimilates were being used for fruit growth and only 10% for vegetative growth as the plant completed its fruit loading for the highest-yielding peanut cultivars. They found that the lowest yielding cultivar, Dixie Runner, partitioned only 38% of its assimilate to its fruit while the highest yielding, Early Bunch, partitioned 78%. In this experiment (Experiment II) I found that the pod growth rate of Florunner was 5.9 g/m^2/da, which is similar to the results obtained in the 1976 experiment (Experiment I). Within genotypes, the pod growth rate of peanut plants was constant between years, while the crop growth rate varied. Williams et al. (1976) reported that defoliation of the peanut plant decreased both stem and pod growth rate. The pod growth rate was increased by pod removal and was decreased by defoliation. Boote (1976) studied the fruit growth rate of Florunner peanut in a field experiment. He found that fruit set during the first four weeks of pegging had similar linear growth rate (33.5 mg/da/fruit). In soybean, Hanway and Weber (1971) found that pods of all cultivars increased in weight at a rate of 5.1 g/m^2/da.

In my experiment, 12 peanut genotypes had a higher pod growth rate than Florunner, six had a similar rate and four had a lower rate (Table 3).

The days to maturity and the pod dry matter yield are presented in Table 4. UF 77416 produced the highest pod dry matter yield of 7472 kg/ha and Dixie Runner the lowest yield of 3220 kg/ha. The pod dry matter yield of UF 77416 was not significantly different from Early Bunch, UF 77405, and UF 77707, but was significantly different from the other 18 genotypes. Seven genotypes (UF 77118, UF 77114, UF 77710, UF 77116, Tifrun, UF 771127, and UF 77617) matured early at 118 days after planting; six genotypes (Early Bunch, Storer's Jumbo Bunch, UF 77402, UF 77117, UF 77707, and GK 3) matured at 125 days. Florunner, UF 73307, UF 77303, UF 77405, UF 77113, and UF 77602 genotypes matured at 132 days. Three genotypes (Dixie Runner, UF 77414, and UF 77416) were late in maturity and required 139 days. UF 77416 appeared to be the genotype with most promising high yield potential. It likely has a longer filling period and a higher assimilate partitioning factor. Duncan (1975) proposed that a maximum yield of peanut can be thought of as being limited by three considerations: fruitfulness, photosynthetic rate, and filling period duration. Duncan (1975) believed that a longer filling period appeared to be the most feasible way to obtain large increases in yield potential.

Table 4. Days to maturity and the pod dry matter yield of 22 peanut genotypes.

Genotype	Days to Maturity	Pod Dry Matter Yield
		kg/ha
UF 77416	139	7472 a
Early Bunch	125	6578 ab
UF 77405	132	6226 abc
UF 77707	125	6226 abc
UF 77117	125	6065 bc
UF 77617	118	6010 bcd
Storer's Jumbo Bunch	125	5835 bcd
UF 77602	132	5812 bcd
UF 77303	132	5800 bcd
UF 77414	139	5725 bcd
UF 77113	132	5483 bcd
UF 77710	118	5445 bcd
UF 77118	118	5390 bcd
UF 77402	125	5368 bcd
Florunner	132	5312 bcd
UF 77116	118	5277 bcd
GK 3	125	5096 bcd
Tifrun	118	4996 cd
UF 77114	118	4965 cd
UF 771127	118	4866 cd
UF 73307	132	4534 d
Dixie Runner	139	3220 e

Means with the same letter (a, b, c, and d) are not significantly different at alpha level = .05. CV = 15.80

EXPERIMENT III. EFFECT OF PEANUT ROOT-KNOT NEMATODE ON THE PHYSIOLOGICAL ASPECT OF PEANUT YIELDS

Objective

The objective of this investigation was to study the effect of peanut root-knot nematode (Meloidogyne arenaria) on the physiological aspects of peanut yield by growth analysis.

Materials and Methods

The experiment was conducted at the Agronomy Farm (Bivens Arm), University of Florida, in the summer of 1978. Nematodes used in this study were from stock colonies established and maintained on tomato, Lycopersicon esculentum Mill. 'Walker,' from eight egg masses of Meloidogyne arenaria obtained from Dr. D. W. Dickson, Department of Entomology and Nematology, University of Florida, collected orignially from peanut roots from a field in Levy County, Florida. The root-knot nematode population was allowed to multiply on tomato roots for about 60 days before being used in the experiment.

UF 77118, an early maturity bunch-type peanut breeding line, obtained from Dr. A. J. Norden, was used in the experiment. Steam-treated soil was mixed with vermiculite at the ratio of 2:1, a 560 kg/ha rate of 2-10-10 fertilizer applied, the soil placed in 25-cm pots, and one seed planted per pot. A total of 155 pots were placed in the open field and spaced 25 cm x 25 cm. This spacing resulted in 16 plants per square meter which is within the range of optimum yield

for a bunch-type peanut. At the appropriate time, twelve egg masses of M. arenaria were separated from tomato roots and added to each treatment pot in a small hole made around the peanut seedling.

A completely randomized design with five replications was used. There were five treatments applied in this experiment:

1) Control (no inoculum)

2) Inoculated at seeding

3) Inoculated at flowering (30 days after planting)

4) Inoculated at pegging (45 days after planting)

5) Inoculated at complete ground cover (60 days after planting).

Insecticides and fungicides were applied at recommended levels for optimum yield. Overhead irrigation was applied at planting, at the time of inoculation, and once a day during periods of low rainfall to insure adequate soil moisture.

Sampling began 15 days after planting and continued at 15 day intervals until the plants reached maturity. One-plant samples in each replication were used to determine the individual plant characteristics. The length of the main stem was measured and the number of pegs and pods was recorded. After separation into stems, roots, leaves, and pods, the plants were dried at 90° C and the dry weight recorded for vegetative, reproductive, and total growth. Before drying, the leaves separated from one plant sample were measured on a Hayashi Denko Co., Ltd., Automatic Area Meter, Type AAM-5, for calculation of the Leaf Area Index (LAI). From the leaf area per plant and the plant population of the crop, the LAI was calculated.

Results and Discussion

Effect of Root-Knot Nematode on Ground Cover and Leaf Area Index

UF 77118 peanut breeding line began to emerge nine days after planting. Ground cover increased geometrically and reached complete ground cover at 60 days. At this period canopy photosynthesis maximized as a result of the 100% light interception. McCloud (1974), Kassam et al. (1975), and McGraw (1977) reported that complete ground cover is reached with an LAI of between three and four. The LAI increased (Table 5) geometrically from day 15 to day 60. At day 75 the LAI decreased rapidly until the end of the growing season. The early decline was thought to be the effect of leaf spot diseases, insect attack, and senescence. At 60 days after planting, there was no significant difference between the control and treatment inoculated at complete ground cover. The treatment inoculated at seeding and at flowering showed a significant decrease in LAI. There was a significant decrease in LAI for the treatment which was inoculated at pegging but a less serious effect when compared to the treatments which were inoculated at seeding and at flowering. The control and the treatment which was inoculated at complete ground cover produced the highest LAI, 3.2, at 60 days after planting. LAI values for all treatments declined after day 60. A similar observation was found by McCloud (1974) and McGraw (1977), who noted that the canopy reached full ground cover at about 60 days when LAI was 3.0. Boote et al. (1978) reported that removal of 25% of the leaf area reduced $^{14}CO_2$ uptake 30% and canopy carbon exchange rate (CER) by 35%. They noted that defoliating insects and Cercospora leafspot are major yield reducing pests of peanut. Photosynthesis of diseased canopies was reduced more than the proportion of the LAI lost, because

Table 5. Effect of the root-knot nematode, Meloidogyne arenaria, on Leaf Area Index when inoculated at different growth stages of the peanut breeding line UF 77118.

Days	Control no Inoculum	Inoculated at Seeding	Inoculated at Flowering	Inoculated at Pegging	Inoculated at Complete Ground Cover
	- LAI -				
15	0.08	0.06			
30	1.08	0.85			
45	2.38	1.30	1.87		
60	3.20 a	2.08 c	2.27 c	2.76 b	
75	2.65	1.31	1.81	1.80	2.33
90	0.88	1.25	0.69	0.67	1.12
100	0.38	0.32	0.03	0.12	0.52
110	0.03	0.10	0.05	0.00	0.22

Means with the same letter (a, b, and c) are not significantly different at alpha = 0.05. CV = 9.91. Standard deviation = 0.267.

Cercospora reduced CO_2 uptake per unit of remaining leaf area. Loveys and Bird (1973) found that the rate of photosynthesis of tomato seedlings after infestation with Meloidogyne Javanica larvae decreased as compared with uninfested controls.

Effect of Root-Knot Nematode on Stem Dry Weight and Main Stem Height

Stem dry weight expressed in g/plant is presented in Table 6, and the main stem height measured in centimeters is shown in Table 7. Stem dry weight and main stem height were decreased significantly in the treatments which were inoculated at seeding and flowering. There were no significant differences between the controls and those treatments inoculated at pegging and at complete ground cover. Those inoculated at seeding had the greatest decrease in stem dry weight and stem height. A similar observation was reported by Milne (1972) in tobacco, Madamba et al. (1965) in pepper, peanut, and Crotalaria, and Orion and Minz (1969) in tomato. Stunting and poor growth may be caused by reduced translocation, inadequate absorption, abnormal production of growth regulators, reduction in the number of roots, and toxic metabolites.

Effect of Root-Knot Nematode on Leaf Dry Weight

Leaf dry weight expressed in g/plant is presented in Table 8. At 75 days after planting the control treatment produced a leaf dry weight of 7.90 g/plant, which is significantly greater than the 3.91 g/plant for the treatment inoculated at seeding time. There was no significant difference in leaf dry weights between the control and the treatments which were inoculated at flowering, pegging, and full ground cover.

Table 6. Effect of the root-knot nematode, Meloidogyne arenaria, on stem dry weight when inoculated at different growth stages of the peanut breeding line UF 77118.

Days	Control no Inoculum	Inoculated at Seeding	Inoculated at Flowering	Inoculated at Pegging	Inoculated at Complete Ground Cover
	g/plant				
15	0.53	0.46			
30	3.00	2.36			
45	9.80	5.38	7.52		
60	15.14	11.11	11.85	14.26	
75	19.78 a	8.97 b	12.51 b	17.67 a	17.98 a
90	17.13	10.95	11.39	14.87	23.13
100	13.58	8.27	9.80	16.10	11.55
110	16.57	7.48	9.16	15.59	15.07

Means with the same letter (a, b) are not significantly different at alpha = 0.05.
CV = 22.96. Standard deviation = 3.53.

Table 7. Effect of the root-knot nematode, Meloidogyne arenaria, on main stem height when inoculated at different growth stages of the peanut breeding line UF 77118.

Days	Control no Inoculum	Inoculated at Seeding	Inoculated at Flowering	Inoculated at Pegging	Inoculated at Complete Ground Cover
	- cm -				
15	7.7	6.0			
30	20.3	15.8			
45	24.8	20.4	21.9		
60	25.0 a	21.5 b	20.7 b	24.9 a	
75	28.7	18.7	22.2	25.8	24.4
90	28.0	17.4	20.4	20.6	27.4
100	22.0	17.5	18.5	21.2	19.6
110	23.4	16.5	20.0	23.1	21.5

Means with the same letter (a, b) are not significantly different at alpha = 0.05.
CV = 7.99. Standard deviation = 1.87.

Table 8. Effect of the root-knot nematode, Meloidogyne arenaria, on leaf dry weight when inoculated at different growth stages of the peanut breeding line UF 77118.

Days	Control no Inoculum	Inoculated at Seeding	Inoculated at Flowering	Inoculated at Pegging	Inoculated at Complete Ground Cover
	g/plant				
15	0.25	0.17			
30	2.83	2.34			
45	7.88	4.48	5.85		
60	8.24	6.22	6.77	9.54	
75	7.90 a	3.91 c	5.40 bc	5.39 bc	6.95 ab
90	2.62	3.75	2.01	1.98	3.35
100	1.13	0.96	0.09	0.36	1.57
110	0.10	0.31	0.15	0.00	0.65

Means with the same letter (a, b, and c) are not significantly different at alpha = 0.05. CV = 29.59. Standard deviation = 1.749.

Effect of Root-Knot Nematode on Number of Pegs and Pods

Number of pegs and number of pods are presented in Tables 9 and 10, respectively. At 28 days after planting the peanut plant started flowering and two weeks later it started pegging. Peanut plants inoculated with Meloidogyne arenaria at planting and at flowering had significantly fewer pegs compared to the control and those treatments inoculated at pegging and at full ground cover. Machmer (1951) reported that early infection of the peanut peg by M. arenaria is detrimental to the seed embryo. An (1978) found that shading of peanut at the peak flowering stage reduced the number of flowers per plant. Flowers open at the time of shading did not produce pegs. Shading at pegging time reduced total peg number. She also reported that shade caused a major reduction in number of both pegs and fruits. Dickson and Waites (1978) reported that additional at-pegging nematicide treatments increased peanut yields in soil infested with M. arenaria.

At 45 days after planting the peanut plant started pegging, and one week later the pod began to fill. At 75 days the control treatment produced 45 pods/plant compared to the treatments inoculated at seeding and at flowering which produced only 28 and 29 pods/plant, respectively. After 75 days the number of pods decreased both on the infected and uninfected plants. Machmer (1951) reported that M. arenaria caused galling on all underground parts of the peanut plants including the pods which appear warty. Pods are often galled heavily and are severed easily. Chandola et al. (1973) reported that the number of peanut pods/plant had a direct effect on seed yield. The number of primary branches and the fresh weight of pods also gave a positive effect, although the number of secondary branches had a negative effect on yield.

Table 9. Effect of the root-knot nematode, Meloidogyne arenaria, on number of pegs when inoculated at different growth stages of the peanut breeding line UF 77118.

Days	Control no Inoculum	Inoculated at Seeding	Inoculated at Flowering	Inoculated at Pegging	Inoculated at Complete Ground Cover
	- - - - - - - - - - - - - - - - - - number - - - - - - - - - - - - - - - - - -				
45	8	4	4		
60	49	38	31	53	
75	27 a	18 b	14 b	26 a	26 a
90	35	24	29	25	49
100	30	14	14	23	21
110	21	16	11	20	24

Means with the same letter (a, b) are not significantly different at alpha = 0.05.
CV = 23.83. Standard deviation = 5.377.

Table 10. Effect of the root-knot nematode, Meloidogyne arenaria, on number of pods when inoculated at different growth stages of the peanut breeding line UF 77118.

Days	Control mo Inoculum	Inoculated at Seeding	Inoculated at Flowering	Inoculated at Pegging	Inoculated at Complete Ground Cover
	- - - - - - - - - - - - - - - - - -	number		- - - - - - - - - - - - - - - - - -	
60	27	19	18	28	
75	45 a	28 b	29 b	39 a	41 a
90	35	24	21	31	43
100	32	18	24	33	25
110	29	17	15	23	26

Means with the same letter (a, b) are not significantly different at alpha = 0.05.
CV = 17.9. Standard deviation = 6.582.

Effect of Root-Knot Nematode on Crop Growth Rate

Total dry weight expressed in g/plant is presented in Table 11, and the linear crop growth rate is shown in Table 12. Total dry weight increased linearly from day 30 to day 75. After day 75 the total phytomass decreased until the crop reached the maturity phase at about 110 days. At 75 days after planting the control treatment produced the highest total phytomass of 40.2 g/plant, as compared to the treatment which was inoculated at seeding which produced only 19.4 g/plant and at flowering (26.2 g/plant). There was no significant difference between the treatments inoculated at pegging and at complete ground cover which had a total phytomass of 34.6 and 37.6 g/plant, respectively. The crop growth rate from 30 to 75 days for the uninoculated treatment was 0.75 g/plant/da which is equivalent to 11.6 g/m^2/da and the equation for this relationship is $Y = 16.6722 + 0.7507\ X$ with an r of 0.9986. Peanut plants which were inoculated at seeding had a crop growth rate of only 0.367 g/plant/da. Early infection by M. arenaria decreased the crop growth rate about 50%. In Experiment II, the crop growth rate of this peanut breeding line (UF 77118) was 22.5 g/m^2/da (Table 3), while in Experiment III, it was 11.6 g/m^2/da. In Experiment II the plants were grown in the ground while in Experiment III they were grown in pots. In the field experiment this peanut breeding line obtained more optimum cultural practices compared to the pot experiment. The pot experiment had decreased crop growth rates of nearly 50% as compared to the field experiment. Many factors are recognized as limiting crop growth rate. Some factors (insects, diseases, weeds) directly reduce the peanut yield potential; that is, they reduce the yield that might have been achieved with the particular crop under that environment. A

Table 11. Effect of the root-knot nematode, Meloidogyne arenaria, on total phytomass when inoculated at different growth stages of the peanut breeding line UF 77118.

Days	Control no Inoculum	Inoculated at Seeding	Inoculated at Flowering	Inoculated at Pegging	Inoculated at Complete Ground Cover
	- - - - - - - - - - - - - - - - - - g/plant - - - - - - - - - - - - - - - - - -				
15	0.78	0.63			
30	5.83	4.70			
45	17.68	9.85	13.37		
60	27.30	19.43	20.75	30.41	
75	40.16 a	19.84 c	26.20 bc	34.55 ab	37.61 a
90	34.02	23.63	22.72	27.95	41.28
100	32.31	18.02	20.39	30.39	28.44
110	37.46	16.98	16.64	29.57	31.57

Means with the same letter (a, b) are not significantly different at alpha = 0.05.
CV = 20.59. Standard deviation = 6.524.

Table 12. Linear regression equation indicating the effect of the root-knot nematode, Meloidogyne arenaria, on crop growth rate, expressed in grams per plant per day, when inoculated at different growth stages of the peanut breeding line UF 77118.

Treatments	Linear Regression Equation
Control	Y = -16.6722 + 0.7507 X r = 0.998
Inoculated at seeding	Y = -5.7969 + 0.3666 X r = 0.954
Inoculated at flowering	Y = -7.4384 + 0.4566 X r = 0.997
Inoculated at pegging	Y = -12.4988 + 0.6593 X r = 0.980
Inoculated at complete ground cover	Y = -14.6378 + 0.6998 X r = 0.999

second group of factors, such as nutrients, stand densities, leaf orientation, and row width, can also affect yield. Mitchell (1970) reported that most crop management practices are directed toward balancing these factors in order to obtain a range of yields up to the maximum.

Effect of Root-Knot Nematode on Pod Growth Rate

Pod dry weight yield (g/plant) is shown in Table 13 and the pod growth rate is presented in Table 14. The pod filling period began 60 days after planting. The highest pod dry matter yield of 3223 kg/ha was from the uninoculated plants as compared to 1424 from plants inoculated at seeding. In the field experiment in 1977, UF 77118 peanut breeding line produced the highest pod dry matter yield of 5390 kg/ha (Table 4). The linear pod growth rate started from day 60 and continued to day 110. Analysis of this linear pod filling phase for the control treatment gave a regression equation $Y = -13.9189 + 0.3197\ X$ ($r = 0.959$), as compared to the treatment which was inoculated at seeding which gave an equation $Y = -4.4961 + 0.1343\ X$ ($r = 0.895$). The control treatment had a maximum pod growth rate of 4.96 $g/m^2/da$ as compared to the pod growth rate obtained from the 1977 experiment of 7.40 $g/m^2/da$ (Table 3). Nematodes inoculated at the later stages of growth did not significantly reduce pod dry matter yield. Nonetheless, quality might have been affected since the pods were galled with a greater degree of galling occuring on those inoculated earliest. Seeds were not examined for quality.

Table 13. Effect of the root-knot nematode, Meloidogyne arenaria, on pod dry matter yield when inoculated at different growth stages of the peanut breeding line UF 77118.

Days	Control no Inoculum	Inoculated at Seeding	Inoculated at Flowering	Inoculated at Pegging	Inoculated at Complete Ground Cover
	- - - - - - - - - - - - - - - - - - g/plant - - - - - - - - - - - - - - - - - -				
60	4.0	2.1	2.1	3.6	
75	12.5	7.0	8.3	11.5	12.7
90	14.3	8.9	9.3	11.1	14.8
100	17.6 a	8.8 b	10.5 ab	13.9 ab	15.3 ab
110	20.8	9.2	7.3	14.0	15.8

Means with the same letter (a, b) are not significantly different at alpha = 0.05.
CV = 38.99. Standard deviation = 5.157.

Table 14. Linear regression equation indicating the effect of the root-knot nematode, Meloidogyne arenaria, on pod growth rate, expressed in grams per plant per day, when inoculated at different growth stages of the peanut breeding line UF 77118.

Treatments	Linear Regression Equation	
Control	Y = -13.9189 + 0.3197 X	r = 0.9589
Inoculated at seeding	Y = -4.4961 + 0.1343 X	r = 0.8950
Inoculated at flowering	Y = -8.5005 + 0.1977 X	r = 0.9250
Inoculated at pegging	Y = -8.5211 + 0.2283 X	r = 0.8950
Inoculated at complete ground cover	Y = -10.8269 + 0.2769 X	r = 0.9138

SUMMARY AND CONCLUSIONS

Florunner and Apollo peanut cultivars reached 100% ground cover 64 days after planting. Flowering of Florunner ceased at 85 days, about the time a linear pod filling rate was achieved, whereas Apollo continued to flower although its fruit load appeared to be set at 113 days, suggesting that Apollo diverts a smaller proportion of its photosynthate to pod filling.

The crop growth rate for Florunner and Apollo was the same, averaging 126 kg/ha/da. The pod growth rates of the two cultivars were quite different, 60 kg/ha/da for Florunner compared to 43 for Apollo. The calculated partitioning coefficient for Florunner was 79% compared to 56% for Apollo.

The number of pods per plant of both cultivars was not appreciably different. The maximum pod number of Florunner was an average of 34 at 120 days whereas Apollo produced an average of 30 pods at 113 days. Florunner produced a pod yield of 4,258 kg/ha at 120 days, while Apollo produced 3,087 kg/ha at 134 days. The difference between the two cultivars was due to the differential partitioning of assimilate to the reproductive and vegetative plant parts.

In the 1977 field experiment the crop growth rate for the 22 peanut genotypes averaged 23.1 $g/m^2/da$. Early Bunch and UF 771127 had the highest crop growth rate of 29.9 $g/m^2/da$ compared to Storer's Jumbo Bunch and Dixie Runner which produced only 16.5 $g/m^2/da$. UF 77416 and

UF 77117 produced the highest pod growth rate of 9.29 $g/m^2/da$ compared to Dixie Runner and UF 73307 genotypes which gave only 3.22 $g/m^2/da$.

There was a significant difference in crop growth rate for the 22 peanut genotypes. It became clear that in the low producing genotypes there was more growth of the tops during the fruit filling period than in the high-producing genotypes. Thus, the primary reason for the yield differences among the 22 peanut genotypes was a differential partitioning of assimilates to fruit.

UF 77416 (breeding line) produced the highest pod dry matter yield of 7472 kg/ha as compared to Dixie Runner cultivar which obtained only 3220 kg/ha. UF 77416 appeared to be the most promising peanut breeding line which likely has a longer filling period (matured at 139 days) and a higher partitioning assimilate factor. Awareness of these factors could aid in bringing about large increases in peanut production in the future.

In the 1978 pot experiment, early infection by the peanut root-knot nematode not only reduced peanut yield up to 50%, but also affected the crop growth rate, pod growth rate, leaf dry weight, and the leaf area index. Stunting and poor growth were general symptoms of infection. The nematode inoculated at later stages of plant growth did not appreciably reduce peanut yields. To minimize damage, the peanut root-knot nematode (Meloidogyne arenaria) should be controlled at least until the peanut plant starts flowering.

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BIOGRAPHICAL SKETCH

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He is a member of the American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, and the American Peanut Research and Education Association.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

D. E. McCloud, Chairman
Professor of Agronomy

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V. E. Green, Jr.
Professor of Agronomy

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A. J. Norden
Professor of Agronomy

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